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| DECUS NO. | 8-285 |
| TITLE | TELETYPE INPUT-OUTPUT PACKAGE |
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| COMPANY | Institute of Atmospheric Sciences South Dakota School of Mines and Technology Rapid City, South Dakota |
| DATE | December 9, 1969 |
| SOURCE LANGUAGE | PAL-D |

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Title: Teletype Input-Output Package

Author: Garth Peterson

Date: 2 December 1969

Name: TTYP

Programming language: PALD

Core usage: One page, plus location 0.

Abstract:

This is a teletype control package containing subroutines for single-character input and output and for output of packed and open text. These subroutines are single-field oriented, but provide for interrupt-enabled and disabled operation.

Description:

There are nine subroutines:

| <u>Name</u> | <u>Function</u> |
|-------------|--|
| KTREAD | Read one input character unconditionally. |
| KTGET | Get contents of keyboard buffer (conditional input). |
| KTKCL | Clear keyboard buffer. |
| KTKSV | Service keyboard flag interrupt. |
| KTWRT | Write one output character. |
| KTTSV | Service teletype output flag interrupt. |
| KTACPT | Accept keyboard input character and echo it. |
| TYPOP | Type open text. |
| TYPPAK | Type packed text. |

KTREAD, KTGET, and KTACPT return to the calling program with data in the accumulator; all others return with the accumulator cleared to zero. KTWRT takes data from the accumulator upon entry; all others clear the accumulator at the start.

The design of these subroutines is based on the following interrupt philosophy: Under interrupt-disabled operation the user's program consists of a single process which includes all calculations, decision branches, and peripheral device service. The operation of peripherals simultaneously with one another and with the calculating and branching parts of the program is thus limited to the inherent buffering capabilities of the peripheral hardware. Under interrupt-enabled operation the user's program contains first a main process, which makes calculations and decisions and which initiates peripheral operations, and second an interrupt service process, which clears flags and issues such commands as are required by the current states of the peripheral devices [8]. Whenever the interrupt service determines that no more devices currently require service, execution of the main process must resume at the point of interruption. The main process runs primarily with the interrupt facility enabled but with it disabled when instructions are executed which are common to both processes. Thus this teletype package is unsuitable for time-sharing systems, but it can run only one teletype anyway. Interrupt-enabled operation is made to resemble interrupt-disabled operation as closely as possible; therefore buffering of the teletype is actually or virtually limited to hardware buffering, and multiple entry points for the individual subroutines are avoided. Other peripherals can run simultaneously with the teletype as permitted by program logic and the interrupt facility.

If the calling program enables the interrupt facility, the interrupt flag identification routine should contain some coding sequence such as:

```
KSF
SKP
JMS KTKSV
TSF
SKP
JMS KTTSV
```

KTKSV and KTTSV should be called only while the interrupt facility is disabled and only in response to interrupts. No references in the calling program to these two subroutines are needed if the interrupt facility is always disabled. All the remaining subroutines may be called with the interrupt facility enabled or disabled, but only as part of the main process.

The text output subroutines have calling sequences as follows:

```
JMS TYOPN
AREA
```

```
JMS TYPPAK
AREA
```

"AREA" is the address of the first word of the text. The separation of the character string from the subroutine call allows more efficient use of PDP-8 memory pages. TYOPN outputs open text consisting of 8-bit ASCII with one right-justified character per memory word. The text string is terminated by a zero word; however, blank tape can still be punched by means of a non-zero word which is zero in the low-order 8 bits. When writing a program, certain characters, such as carriage return, line feed, rubout, and back arrow, must be written in octal to avoid problems with the Editor program. Most printing characters can be written explicitly, using the single-character assembly facility of PALD or MACRO-8 [2,5]. For example:

```
MESG, 215;212;"M;"E;"S;"S;"A;"G;"E;0
```

At least three characters in the source program are needed for each character in the text, so that open text is inefficient in both the source program and object program. However, open text is more convenient as program-generated text, such as numerical output.

TYPPAK outputs 6-bit stripped ASCII, packed two characters per word, as assembled by PALD or MACRO-8 when the pseudo-op "TEXT" is used [3,6]. Permissible output characters are space, carriage return, line feed, and all the graphics except the at (@), per cent (%), and pound (#) signs. The text is terminated by 00 (octal), which is generated by the assembler, and which is what "@" in the text will compress to. The at sign is therefore a logical choice for a text delimiter. The

per cent and pound signs are compressed in the usual way by the assembler but then converted by TYPPAK to carriage return and line feed respectively [1]. The back arrow is excluded by the Editor, rather than by TYPPAK or the assembler. In addition, if the Editor converts successive spaces in the text to a single tabulate character, the final result in the output will be "I".

Both text subroutines call KTWRT, which the calling program may also access directly. KTWRT loops until the teletype flag rises, or until enough time has elapsed to assure that no flag is pending, and then issues the output command [7]. The entry point KTWRT is immediately followed by a skip and return:

```
KTWRT, 00
SKP
JMP I KTWRT
. . . . .
```

This allows the output of TYPPAK to be diverted to another device when the skip is replaced by a call to the subroutine for that device. For example, suppose "PTWRT" is the name of a fast punch subroutine. Then output can be diverted and restored thus:

```
TAD (JMS I [PTWRT])
DCA KTWRT+1

TAD (SKP)
DCA KTWRT+1
```

Note that "PTWRT" must return to KTWRT+2 with the accumulator cleared. KTWRT must be in its normal condition whenever KTACPT is called. For the PDP-8/S the supplied version of KTWRT should be replaced by:

```
00
00
00
KTWRT, 00
SKP
JMP I KTWRT
DCA KTWRT-2
DCA KTWRT-3
ISZ KTWRT-3
TAD KTWRT-1
SNA CLA
JMP .+3
TSF
JMP .-5
TAD KTWRT-2
TIS
STA
DCA KTWRT-1
JMP I KTWRT
```


The input subroutines KTKCL, KTGET, and KTKCL provide access to the "keyboard buffer," which is an abstraction but which has these properties from the viewpoint of the calling program: The buffer is cleared, or voided, by a program command; keyboard input data loads the buffer, which then remains loaded with this input character until cleared by the program or until reloaded by new input data. KTKCL clears the buffer and should be called before data is read from the teletype to avoid inputting spurious characters. KTKCL provides unconditional input; after entry KTKCL loops until the keyboard buffer contains data, then clears the buffer, and returns with the input data in the accumulator and also in core location KTNEXT. KTGET is a conditional input subroutine which shows the current contents of the keyboard buffer in the accumulator but which does not clear the buffer. If the buffer is void, it sets the accumulator to -1. KTGET is called by KTKCL and may be called directly by the user's program to determine whether or not a teletype key has been pressed. In order to determine the status of the interrupt facility, KTGET accesses location 0; the calling program must therefore avoid this location even if the interrupt facility is never used. The interrelation of KTKCL, KTGET, and KTKCL may be made clearer by the following examples of how these subroutines would be written if the interrupt facility were always disabled. Here the "keyboard buffer" is in fact the hardware buffer, provided that a keyboard flag must be present for the buffer to be considered loaded.

```

KTKCL, 00
  KCC
  JMP I KTKCL
/
KTGET, 00
  CLA
  KRS
  KSF
  STA
  JMP I KTGET
/
KTKCL, 00
  JMS KTGET
  SPA
  JMP .-2
  DCA KTNEXT
  KCC
  TAD KTNEXT
  JMP I KTKCL
  KTNEXT, 00

```

Interrupt-enabled operation and teletype paper tape input are not fully compatible. This is a hardware characteristic and cannot readily be offset in programming; a fairly large input buffer in memory is usually required. If KTKCL is used for paper tape input with the interrupt facility enabled, successive calls must occur within 100 milliseconds

to avoid loss of data; if the teletype reader is ready, the tape will advance continuously even when input is not requested. Under interrupt-disabled operation the tape advances by one character for each call to KTREAD.

KTACPT inputs characters from the keyboard and echoes them on the teleprinter. It first clears the keyboard buffer, then reads one character, echoes it, and returns with the character in the accumulator and in KTNEXT. All characters are typed as read except carriage return, which is echoed as carriage return plus line feed. KTACPT is not suitable for paper tape input because of this double echo and because KTKCL should be called only once at the beginning of a paper tape, not repeatedly while the tape is read. Paper tape input with teletype echo is performed by this coding sequence:

```
JMS KTREAD
JMS KTWRTTE
TAD KTNEXT
```

This teletype control package is intended for use by programs which run entirely within 4096 words of memory or which use extended memory only as fast-access auxiliary data storage. Its use on a multiple-field PDP-8 is subject to these restrictions: Each subroutine must be called with the data field matching the instruction field, and it will return only to locations in the field where it resides. Location 0 must be avoided in any field where KTGET is called. Interrupt-enabled operation is limited to field 0. Text for TYPOPN or TYPPAK must not "wrap around" from location 7777 to location 0.

It can be useful to patch the input and output functions of the PDP-8 floating-point interpreter [4] into the teletype package, allowing floating-point input and output with the interrupt facility enabled. The following patches will do this:

```
*7344+1 /OUTPUT PATCH
JMS I .+2
JMP I 7344
KTWRTTE

*7142+1 /INPUT PATCH
JMS I [KTKCL] /OMIT IF PT INPUT
*7142+2
SKP
KTREAD
JMS I .-1
```

These patches should be assembled along with the main program, which must be loaded into core after the floating-point interpreter.

This subroutine package is supplied in ASCII, both with and without comments, and can be assembled as one page of core in the user's program. The first line has the pseudo-op "PAGE", which is the only exception to PAL III, and the last line is a dollar sign. There are 11 labels and no references to auto-index registers.

References:

1. Digital Equipment Corporation, Alphanumeric Message Typeout, Digital-8-18-Sym, February 16, 1967.
2. idem, PAL-D Disk Assembler Programmer's Reference Manual, DEC-D8-ASAA-D, April 1968, p. 1-12.
3. ibidem, p. 2-2.
4. idem, PDP-8 Floating-Point System Programming Manual, DEC-08-YQYA-D, 1968.
5. idem, MACRO-8 Programming Manual, DEC-08-CMAA-D, 1965, p. 5-12.
6. ibidem, pp. 6-3, 6-4.
7. Fichtenbaum, Matthew L., to Mrs. Angela J. Cossette (DECUS Executive Secretary), June 7, 1967, distributed to members of Digital Equipment Computer Users Society.
8. Wirth, Niklaus, "On Multiprogramming, Machine Coding, and Computer Organization," Communications of the ACM, vol. 12, no. 9 (Sept. 1969), pp. 489-498.

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// JOB T 0002 0002 0002 13670

| LOG DRIVE | CART SPEC | CART AVAIL | PHY DRIVE |
|-----------|-----------|------------|-----------|
| 0000 | 0001 | 0001 | 0000 |
| 0001 | 0002 | 0002 | 0001 |

V2M6 16K SDSMT COMP CNTR 05DEC69

// * GARTH PETERSON 50120

// XEQ PTTCD

KTACPT 0274
KTGET 0213
KTKCL 0225
KTKSV 0232
KTNEXT 0211
KTPA 0351
KTREAD 0200
KTTSV 0265
KTWRTE 0242
TYPOPN 0311
TYPPAK 0325

*

| PAGE | | /***** | |
|------------------|------|--------------|--|
| /TTY I/O PACKAGE | | | |
| /11MR68, 30NV69 | | | |
| / | | | |
| 0200 | 0000 | KTREAD, 00 | /SUBR, READ KEYBOARD UNCONDITIONALLY |
| 0201 | 4213 | JMS KTGET | /GET INPUT CHARACTER, IF ANY |
| 0202 | 7510 | SPA | |
| 0203 | 5201 | JMP .-2 | /IF NONE, TRY AGAIN |
| 0204 | 3211 | DCA KTNEXT | /DEPOSIT INPUT CHARACTER |
| 0205 | 7240 | STA | |
| 0206 | 3212 | DCA KTNEXT+1 | /MARK BUFFER IN CORE EMPTY |
| 0207 | 1211 | TAD KTNEXT | |
| 0210 | 5600 | JMP I KTREAD | /RETURN WITH INPUT IN AC |
| 0211 | 0000 | KTNEXT, 00 | /+0 TELETYPE INPUT WORD |
| 0212 | 0000 | 00 | /+1 TELETYPE INPUT BUFFER |
| / | | | |
| 0213 | 0000 | KTGET, 00 | /SUBR, GET TELETYPE INPUT CHARACTER IF |
| 0214 | 7200 | CLA | / ANY |
| 0215 | 3000 | DCA 0 | /LOCATION 0 HOLDS RETURN ADDRESSES OF |
| 0216 | 6031 | KSF | / INTERRUPTS |
| 0217 | 5223 | JMP .+4 | /BRANCH IF NO FLAG, LOOK FOR CHARACTER |
| 0220 | 1000 | TAD 0 | / IN CORE |
| 0221 | 7650 | SNA CLA | /SKIP IF FLAG CAUSED INTERRUPT |
| 0222 | 4232 | JMS KTKSV | /READ HARDWARE BUFFER INTO CORE |
| 0223 | 1212 | TAD KTNEXT+1 | /GET BUFFER CHARACTER, AC= -1 IF NONE |
| 0224 | 5613 | JMP I KTGET | |
| / | | | |
| 0225 | 0000 | KTKCL, 00 | /SUBR, CLEAR OUT PREVIOUS KEYBOARD INPUT |
| 0226 | 6032 | KCC | /CLEAR HARDWARE FLAG WHEN INTERRUPT |
| 0227 | 7240 | STA | / DISABLED |
| 0230 | 3212 | DCA KTNEXT+1 | /MARK BUFFER IN CORE EMPTY |
| 0231 | 5625 | JMP I KTKCL | |
| / | | | |
| 0232 | 0000 | KTKSV, 00 | /KEYBOARD INPUT INTERRUPT & FLAG SERVICE |
| 0233 | 6036 | KRB | /CLEAR FLAG, READ BUFFER, ALLOW NEW CHAR |
| 0234 | 3212 | DCA KTNEXT+1 | /SAVE CHARACTER |
| 0235 | 5632 | JMP I KTKSV | |
| / | | | |
| 0236 | 0000 | 00 | /-4 HIGH-ORDER TIME COUNT |
| 0237 | 0000 | 00 | /-3 LOW-ORDER TIME COUNT |
| 0240 | 0000 | 00 | /-2 OUTPUT CHARACTER |
| 0241 | 0000 | 00 | /-1 BUSY LATCH, -1 = BUSY, 0 = NOT BUSY |
| 0242 | 0000 | KTWRTE, 00 | /SUBR, TELETYPE OUTPUT |
| 0243 | 7410 | SKP | /PATCH HERE TO DIVERT TO ANOTHER DEVICE |
| 0244 | 5642 | JMP I KTWRTE | |
| 0245 | 3240 | DCA KTWRTE-2 | /SAVE CHARACTER |
| 0246 | 7346 | CLL STA RTL | /AC = -3 |
| 0247 | 3236 | DCA KTWRTE-4 | /INITIALIZE TIME COUNT (140 MS MIN) |
| 0250 | 2237 | ISZ KTWRTE-3 | /BEGIN LOOP |
| 0251 | 7410 | SKP | |
| 0252 | 2236 | ISZ KTWRTE-4 | /SKIP IF TIME COUNT DONE, EXPECT NO FLAG |
| 0253 | 1241 | TAD KTWRTE-1 | /CHECK BUSY LATCH |
| 0254 | 7650 | SNA CLA | /SKIP IF LATCH ON AND COUNT NOT DONE |
| 0255 | 5260 | JMP .+3 | /BRANCH IF NOT BUSY |
| 0256 | 6041 | TSF | /SKIP IF FLAG, INTERRUPT MAY BE DISABLED |
| 0257 | 5250 | JMP .-7 | /PREVIOUS CHARACTER NOT DONE, TRY AGAIN |
| 0260 | 1240 | TAD KTWRTE-2 | /GET CHARACTER |
| 0261 | 6046 | TLS | /START TELETYPE |
| 0262 | 7240 | STA | |
| 0263 | 3241 | DCA KTWRTE-1 | /MARK BUSY |

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|------|------|----------------|---------------------------------------|
| 0264 | 5642 | JMP I KTWRT | |
| | | / | |
| 0265 | 0000 | KTTSV, 00 | /TELETYPE OUTPUT INTERRUPT SERVICE |
| 0266 | 6042 | TCF | /CLEAR FLAG |
| 0267 | 7200 | CLA | |
| 0270 | 3241 | DCA KTWRT-1 | /MARK NOT BUSY |
| 0271 | 5665 | JMP I KTTSV | |
| | | / | |
| 0272 | 0212 | 212 | |
| 0273 | 7563 | -215 | |
| 0274 | 0000 | KTACPT, 00 | /ACCEPT (AND ECHO) KEYBOARD INPUT |
| 0275 | 4225 | JMS KTKCL | /CLEAR KEYBOARD BUFFER |
| 0276 | 4200 | JMS KTREAD | /READ KEYBOARD |
| 0277 | 4242 | JMS KTWRT | /ECHO ON TELEPRINTER |
| 0300 | 1211 | TAD KTNEXT | |
| 0301 | 1273 | TAD KTACPT-1 | /CHECK FOR CARRIAGE RETURN |
| 0302 | 7640 | SZA CLA | |
| 0303 | 5306 | JMP .+3 | |
| 0304 | 1272 | TAD KTACPT-2 | /IF CARRIAGE RETURN, SUPPLY LINE FEED |
| 0305 | 4242 | JMS KTWRT | |
| 0306 | 1211 | TAD KTNEXT | /GET CHARACTER |
| 0307 | 5674 | JMP I KTACPT | /RETURN |
| | | / | |
| 0310 | 0000 | 00 | |
| 0311 | 0000 | TYPOPN, 00 | /TYPE MESSAGE OF OPEN TEXT |
| 0312 | 7200 | CLA | / JMS TYPOPN (EFFECTIVE) |
| 0313 | 1711 | TAD I TYPOPN | / ADDRESS-OF-MESSAGE |
| 0314 | 3310 | DCA TYPOPN-1 | / (NEXT INSTRUCTION) |
| 0315 | 2311 | ISZ TYPOPN | |
| 0316 | 1710 | TAD I TYPOPN-1 | |
| 0317 | 2310 | ISZ TYPOPN-1 | |
| 0320 | 7450 | SNA | |
| 0321 | 5711 | JMP I TYPOPN | /ZERO WORD TERMINATES MESSAGE |
| 0322 | 4242 | JMS KTWRT | /WRITE CHARACTER |
| 0323 | 5316 | JMP .-5 | |
| | | / | |
| 0324 | 0000 | 00 | / TEXT POINTER |
| 0325 | 0000 | TYPPAK, 00 | /TYPE PACKED TEXT |
| 0326 | 7200 | CLA | / JMS TYPPAK (EFFECTIVE) |
| 0327 | 1725 | TAD I TYPPAK | / AREA |
| 0330 | 3324 | DCA TYPPAK-1 | / (NEXT INSTRUCTION) |
| 0331 | 2325 | ISZ TYPPAK | |
| 0332 | 1724 | TAD I TYPPAK-1 | /GET FIRST CHAR IN WORD |
| 0333 | 4351 | JMS KTPA | |
| 0334 | 1724 | TAD I TYPPAK-1 | /GET SECOND CHAR IN WORD |
| 0335 | 7006 | RTL | |
| 0336 | 7006 | RTL | /LEFT-JUSTIFY |
| 0337 | 7006 | RTL | |
| 0340 | 4351 | JMS KTPA | |
| 0341 | 2324 | ISZ TYPPAK-1 | /INCREMENT POINTER |
| 0342 | 5332 | JMP TYPPAK+5 | |
| 0343 | 0245 | 245 | /PER CENT |
| 0344 | 7750 | 215-245 | /CR - PER CENT |
| 0345 | 7776 | 243-245 | /POUND - PER CENT |
| 0346 | 7747 | 212-243 | /LF - POUND |
| 0347 | 7535 | -243 | / -POUND |
| 0350 | 7700 | 7700 | |
| 0351 | 0000 | KTPA, 00 | /SUBR, PRINT 6-BIT ASCII LEFT |
| 0352 | 0350 | AND KTPA-1 | /CLEAR RIGHT 6 BITS |
| 0353 | 7450 | SNA | |

| | | | |
|------|------|---------------|--|
| 0354 | 5725 | JMP I TYPPAK | /RETURN IF 00 CHAR (NO AT SIGN) |
| 0355 | 7101 | CLL IAC | /AC BIT 11 WILL GO TO CHANNEL 8 |
| 0356 | 7500 | SMA | /LINK WILL GO TO CH 7 (= COMPLEMENT OF |
| 0357 | 7120 | STL | / CH 6) |
| 0360 | 7012 | RTR | /AC 0-5 GO TO CHS 6-1 |
| 0361 | 7012 | RTR | |
| 0362 | 7012 | RTR | /AC HOLDS 8-BIT ASCII |
| 0363 | 1347 | TAD KTPA-2 | |
| 0364 | 7450 | SNA | |
| 0365 | 1346 | TAD KTPA-3 | /CHANGE POUND SIGN TO LINE FEED |
| 0366 | 1345 | TAD KTPA-4 | |
| 0367 | 7450 | SNA | |
| 0370 | 1344 | TAD KTPA-5 | /CHANGE PER CENT TO CARRIAGE RETURN |
| 0371 | 1343 | TAD KTPA-6 | |
| 0372 | 4242 | JMS KTWRT | /WRITE CHARACTER |
| 0373 | 5751 | JMP I KTPA | |
| | | /END, TTY PKG | ***** |

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